UPDATES TO METHODS AND DATA FOR CALCULATING TRANSPORTATION RISK ON RAIL CORRIDORS

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CONTENTS

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1. INTRODUCTION

Since DOE published the Yucca Mountain FEIS (DOE 2002) in 2002, there have been changes in the repository design and operational plans. In addition, there have been changes to some of the basic data DOE uses to estimate radiation doses and radiological impacts. These changes include the use of:

- Updated latent cancer fatality conversion factors
- Updated radiation dosimetry
- Escorts in all areas
- Dedicated trains for shipments
- Updated census data and population escalation period
- Updated estimates of the number of casks shipped to the repository
- Updated estimates of the radionuclide inventories for spent nuclear fuel and high-level radioactive waste
- Updated exposure times and staffing estimates.

The following sections describe the changes that most affect potential impacts for the rail corridors analyzed in the *Corridor-Level Information for the Mina, Carlin, Jean, and Valley Modified Rail Implementing Alternatives Technical Support Document.*

Sections 2 through 9 in this technical memorandum discuss the eight major areas of revision. Section 10 in this technical memorandum presents updated estimates of impacts for sabotage events in rural and urban areas. In addition, the estimates of the Nevada impacts for the rail corridors presented in the Yucca Mountain FEIS included the impacts for the rail corridors and the impacts from the beginning of the rail corridors to the Nevada border. Section 11 in this technical memorandum presents estimates of impacts for the Carlin, Jean, and Valley Modified rail corridors that do not include in the impacts from the beginning of the rail corridors to the Nevada border. These estimates of impacts are based on the methods and data used in the Yucca Mountain FEIS and do not include the updates discussed in Sections 2 through 9 of this technical memo.

2. LATENT CANCER FATALITY CONVERSION FACTORS

In the Yucca Mountain FEIS, DOE based the estimates of latent cancer fatalities on the received radiation dose and on radiation dose-to-health effect conversion factors from the International Commission on Radiological Protection (ICRP 1991). The Commission estimated that for the general population a collective radiation dose of 1 person-rem would yield 0.0005 excess latent cancer fatality. For radiation workers, a collective radiation dose of 1 person-rem would yield an estimated 0.0004 excess latent cancer fatality.

The estimates of latent cancer fatalities in the *Corridor-Level Information for the Mina, Carlin, Jean, and Valley Modified Rail Implementing Alternatives Technical Support Document* are based on the received radiation dose and on radiation dose-to-health effect conversion factors recommended by the Interagency Steering Committee on Radiation Standards (Lawrence 2002). The Committee estimated that a collective radiation dose of 1 person-rem would yield 0.0006 excess latent cancer fatality for the general population and radiation workers.

For workers, an increase in the radiation dose-to-health effect conversion factor from 0.0004 to 0.0006 excess latent cancer fatality per person-rem would increase the estimates of radiological impacts by 50 percent. For members of the public, an increase in the radiation dose-to-health effect conversion factor from 0.0005 to 0.0006 excess latent cancer fatality per person-rem would increase the estimates of radiological impacts by 20 percent.

3. RADIATION DOSIMETRY

Releases of radioactive material to the environment have the potential to affect persons who come in contact with it. Mechanisms for the transport of radioactive material include air, water, soil, and food. The many ways an individual or population can come into contact with radioactive material are known as pathways. In the Yucca Mountain FEIS, five pathways were evaluated:

- Inhalation of radioactive material
- Ingestion of radioactive material
- Inhalation of previously deposited radioactive material resuspended from the ground (known as resuspension)
- External exposure to radioactive material on the ground (known as groundshine)
- External exposure to radioactive material in the air (known as immersion or cloudshine)

The factors for conversion of estimates of radionuclide intake (by inhalation or ingestion) or exposure (by groundshine or immersion) to radiation dose are called dose coefficients. In the Yucca Mountain FEIS, DOE used the inhalation and ingestion dose coefficients from Federal Guidance Report No. 11 (Eckerman, Wolbarst, and Richardson 1988) and the groundshine and immersion dose coefficients from Federal Guidance Report No. 12 (Eckerman and Ryman 1993) to estimate the radiation doses from transportation accidents. These dose coefficients are based on recommendations in International Commission on Radiological Protection Publication 26 (ICRP 1977).

The estimates of radiation doses in the *Corridor-Level Information for the Mina, Carlin, Jean, and Valley Modified Rail Implementing Alternatives Technical Support Document* use the inhalation and ingestion dose coefficients from *The ICRP Database of Dose Coefficients: Workers and Members of the Public* (ICRP 2001) and the groundshine and immersion dose coefficients from Federal Guidance Report No. 13 (EPA 2002) to estimate the radiation doses from transportation accidents. These dose coefficients are based on recommendations of the International Commission on Radiological Protection in ICRP Publication 60 (ICRP 1991) and incorporate the dose coefficients from ICRP Publication 72 (ICRP 1996).

4. ESCORTS IN ALL AREAS

The Yucca Mountain FEIS analysis was based on 2 escorts being present in urban areas and one escort being present in suburban and rural areas. The estimates of the transportation impacts in the *Corridor-Level Information for the Mina, Carlin, Jean, and Valley Modified Rail Implementing Alternatives Technical Support Document* are based on additional escorts being present in all areas.

5. USING DEDICATED TRAINS FOR SHIPMENTS

In the Yucca Mountain FEIS, DOE stated that shipments of spent nuclear fuel and high-level radioactive waste could use regular freight service. One railcar per train that contained spent nuclear fuel or high-level radioactive waste and one escort railcar would be present. Impacts did not include those from buffer cars or locomotives.

The estimates of transportation impacts in the *Corridor-Level Information for the Mina, Carlin, Jean, and Valley Modified Rail Implementing Alternatives Technical Support Document* are based on shipments using dedicated rail service. After the train left the staging yard, there would be no stops on the route to the repository. In addition, DOE would build the rail line and schedule shipments such that exposures to the public who shared the rail line (on-link exposures) would not occur. Shipments of commercial spent nuclear fuel would consist of three casks per train. Shipments of U.S. Navy spent nuclear fuel, DOE spent nuclear fuel, and high-level radioactive waste would consist of five casks per train. In both cases, two buffer railcars, two locomotives, and one escort railcar would also be in the dedicated train. It should be noted that these are the representative numbers of casks per trains and that other numbers of casks per train would be possible.

The Yucca Mountain FEIS analysis assumed DOE would ship these materials on relatively long regular freight trains, and based the accident rates on railcar kilometers. The estimates of transportation impacts in the *Corridor-Level Information for the Mina, Carlin, Jean, and Valley Modified Rail Implementing Alternatives Technical Support Document* are based on using relatively short dedicated trains of 8 to 10 railcars. In addition, the transportation accident rate has been updated to use a combination of rail accident rates based on both train kilometers and railcar kilometers (see Table 1). These rates are for Track Class 3 and include derailments, collisions, and other accidents.

Table 1. Track Class 3 rail accident rates

Train-based accident rate (accidents per train-kilometer)[b]	Railcar-based accident rate (accidents per railcar-kilometer)[c]
7.5×10^{-7}	1.7×10^{-8}

a. Source: Bendixen and Facanha (2007).
b. To convert accidents per train kilometer to accidents per train mile, multiply by 1.6093.
c. To convert accidents per railcar kilometer to accidents per railcar mile, multiply by 1.6093.

The estimates of transportation impacts in the *Corridor-Level Information for the Mina, Carlin, Jean, and Valley Modified Rail Implementing Alternatives Technical Support Document* also use updated rail fatality rates. In the Yucca Mountain FEIS, the rail fatality rate was 2.7×10^{-9} fatality per railcar kilometer (Saricks and Tompkins 1999). In this document, the estimated rail fatality rate is 1.15×10^{-8} fatality per railcar kilometer (DOT 2005).

6. CENSUS DATA AND POPULATION ESCALATION PERIOD

In the Yucca Mountain FEIS, population impacts along the rail corridors were based on 1990 and 2000 Census data and were extrapolated to 2035. The transportation impacts in the *Corridor-Level Information for the Mina, Carlin, Jean, and Valley Modified Rail Implementing Alternatives Technical Support Document* are based on the 2000 Census and impacts are extrapolated to 2067.

7. ESTIMATES OF THE NUMBER OF CASKS TO BE SHIPPED

Since DOE published the Yucca Mountain FEIS in 2002, there have been changes to the numbers of casks that DOE would ship from each origin site to Yucca Mountain. These changes are due to the use of transport, aging, and disposal canisters at commercial nuclear power plants and updated assumptions about cask-handling capabilities at the origin sites (BSC 2007). Table 2 lists the numbers of rail casks and shipments in the Yucca Mountain FEIS and from BSC (2007).

Table 2. Updated numbers of rail casks and shipments[a,b]

Fuel type[c]	FEIS rail casks	FEIS rail shipments	Updated rail casks	Updated rail shipments[d]
PWR SNF	4,679	4,679	4,047	1,363
BWR SNF	2,539	2,539	2,759	929
HLW	1,663	1,663	1,924	387[e]
DOE SNF	465	465	365	74
Navy	300	300	400	80
Totals	**9,646**	**9,646**	**9,495**	**2,833**

a. Updated shipments and casks assume the placement of commercial spent nuclear fuel in transport, aging, and disposal canisters at the reactor sites.

b. Shipments are estimated by origin site and waste type and then summed.

c. BWR = boiling-water reactor; HLW = high-level radioactive waste; PWR = pressurized-water reactor; SNF = spent nuclear fuel.

d. Rail shipments are based on three casks per train for pressurized-water and boiling-water reactor spent nuclear fuel shipments and on five casks per train for high-level radioactive waste, DOE spent nuclear fuel, and Navy spent nuclear fuel shipments.

f. Updated shipments of high-level radioactive waste include high-level radioactive waste at West Valley, New York.

8. ESTIMATES OF THE RADIONUCLIDE INVENTORIES FOR SPENT NUCLEAR FUEL AND HIGH-LEVEL RADIOACTIVE WASTE

Since DOE published the Yucca Mountain FEIS in 2002, there have been changes to the radionuclide inventories for spent nuclear fuel and high-level radioactive waste. The Department will describe these revised inventories in Appendix K of the *Supplemental Yucca Mountain Rail Corridor and Rail Alignment Environmental Impact Statement.*

9. EXPOSURE TIMES AND STAFFING ESTIMATES

The transportation impacts in the Yucca Mountain FEIS were based on 30 hour exposure times for workers at the staging yard for each cask and that no uninvolved workers would be present. The analysis for this document estimated that exposure times would be 2 hours (NRP 2007) and that 65 uninvolved workers would be present at the Carlin, Jean, or Valley Modified staging yard or that 55 uninvolved workers would be present at the Hawthorne staging yard along the Mina Corridor.

10. SABOTAGE AND TERRORISM

It is DOE policy to consider explicitly potential impacts of sabotage events in National Environmental Policy Act documents (Borgstrom 2006). Although this technical memorandum is not a National Environmental Policy Act document, it provides technical information to support such a document (the *Supplemental Yucca Mountain Rail Corridor and Rail Alignment Environmental Impact Statement*), and so addresses these potential impacts at a level of detail commensurate with the analysis that DOE performed for the Yucca Mountain FEIS.

In the Yucca Mountain FEIS (Section 6.2.4.2.3), DOE considered sabotage events for transportation only at the national level. The potential impacts of a national transportation sabotage event would apply to transportation operations in Nevada. The analytical changes described above would also apply to calculations for sabotage events. The analysis for this document updated the calculations and incorporated these changes for the corridor-level information.

In addition, in the Yucca Mountain FEIS, the release fractions from Luna et al. (1999) were used to estimate the impacts of acts of sabotage involving spent nuclear fuel contained in truck or rail casks. In the updated sabotage analysis, the release fractions from Luna (2006) are used to estimate the impacts of acts of sabotage involving spent nuclear fuel in rail casks.

Current estimates indicate that such a sabotage event involving a rail cask in an urban environment could result in 19 latent cancer fatalities in the exposed population, up from the estimated 9 latent cancer fatalities in the Yucca Mountain FEIS. In addition, such an event in a rural area could result in an estimated 0.029 latent cancer fatality. The maximally exposed individual would receive an estimated dose of about 27 rem, which would result in an excess latent fatal cancer risk of 0.016. This is less than the estimated 40-rem dose and 0.020 latent cancer fatality risk in the FEIS. DOE will cover sabotage events in more detail in alignment-level analyses.

11. CORRIDOR IMPACTS FROM THE YUCCA MOUNTAIN FEIS

The estimates of the Nevada impacts for the rail corridors presented in the Yucca Mountain FEIS included the impacts for the rail corridors and the impacts from the beginning of the rail corridors to the Nevada border. Table 3 presents estimates of impacts for the Carlin, Jean, and Valley Modified rail corridors that do not include in the impacts from the beginning of the rail corridors to the Nevada border.

Table 3. Impacts for the rail corridors from the Yucca Mountain FEIS

Rail Corridor	Members of the public (latent cancer fatalities)	Involved workers (latent cancer fatalities)	Vehicle emission fatalities	Radiological accident risk (latent cancer fatalities)	Traffic fatalities	Total fatalities
Caliente	0.0012	0.31	8.0E-4	3.7E-8	0.054	0.36
Jean	0.00085	0.22	3.2E-4	1.5E-8	0.019	0.24
Valley Modified	0.00065	0.22	4.7E-5	2.9E-9	0.016	0.23

Note: Impacts are for the rail corridor and do not include the impacts from the beginning of the rail corridor to the Nevada border.

11. REFERENCES

Bendixen and Facanha 2007	Bendixen, L.; and Facanha, C. 2007. "Rail Accident Rate Calculation Methodology." Memo from L. Bendixen and C. Facanha to M. West (Potomac-Hudson Engineering). Fairfax, Virginia: ICF International. March 30, 2007. ACC: MOL.20070412.0014.
Borgstrom 2006	Borgstrom, C. 2006. "Need to Consider International Destructive Acts in NEPA Documents." Memorandum from C. Borgstrom to DOE NEPA Community. Washington, D.C.: U.S. Department of Energy, Office of NEPA Policy and Guidance.
BSC 2007	BSC (Bechtel SAIC Company) 2007. *Calculation of Transportation Data for SEIS Analyses*. 000-00C-G000-01300-000-00A. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20070523.0036.
DOE 2002	DOE (U.S. Department of Energy) 2002. *Final Environmental Impact Statement for a Geologic Repository for the Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste at Yucca Mountain, Nye County, Nevada.* DOE/EIS-0250. Washington, D.C.: U.S. Department of Energy, Office of Civilian Radioactive Waste Management. ACC: MOL.20020524.0314; MOL.20020524.0315; MOL.20020524.0316; MOL.20020524.0317; MOL.20020524.0318; MOL.20020524.0319; MOL.20020524.0320.
DOT 2005	DOT (U.S. Department of Transportation) 2005. *Railroad Safety Statistics 2004 Annual Report.* Washington, D.C.: U.S. Department of Transportation, Federal Railroad Administration. ACC: MOL.20061031.0151.
Eckerman and Ryman 1993	Eckerman, K.F.; and Ryman, J.C. 1993. *External Exposure to Radionuclides in Air, Water, and Soil, Exposure-to-Dose Coefficients for General Application, Based on the 1987 Federal Radiation Protection Guidance*. EPA 402-R-93-081. Federal Guidance Report No. 12. Washington, D.C.: U.S. Environmental Protection Agency, Office of Radiation and Indoor Air. TIC: 225472.
Eckerman, Wolbarst, and Richardson 1988	Eckerman, K.F.; Wolbarst, A.B.; and Richardson, A.C.B. 1988. *Limiting Values of Radionuclide Intake and Air Concentration and Dose Conversion Factors for Inhalation, Submersion, and Ingestion.* EPA 520/1-88-020. Federal Guidance Report No. 11. Washington, D.C.: U.S. Environmental Protection Agency. ACC: MOL.20010726.0072.
EPA 2002	EPA (U.S. Environmental Protection Agency) 2002. *Federal Guidance Report 13, CD Supplement, Cancer Risk Coefficients for Environmental Exposure to Radionuclides, EPA.* EPA-402-C-99-001 Rev. 1. [Washington, D.C.]: U.S. Environmental Protection Agency. ACC: MOL.20051013.0016.

ICRP 1977	ICRP (International Commission on Radiological Protection) 1977. *Recommendations of the International Commission on Radiological Protection.* Volume 1, No. 3 of *Annals of the ICRP.* ICRP Publication 26. Reprinted 1982. New York, New York: Pergamon Press. TIC: 221568.
ICRP 1991	ICRP (International Commission on Radiological Protection) 1991. "1990 Recommendations of the International Commission on Radiological Protection." Volume 21, No. 1-3 of *Annals of the ICRP.* ICRP Publication 60. New York, New York: Pergamon Press. TIC: 235864.
ICRP 1996	ICRP (International Commission on Radiological Protection) 1996. *Age-Dependent Doses to Members of the Public from Intake of Radionuclides: Part 5 Compilation of Ingestion and Inhalation Dose Coefficients.* Volume 26, No. 1 of *Annals of the ICRP.* Smith, H., ed. ICRP Publication 72. New York, New York: Pergamon Press. TIC: 235870.
ICRP 2001	ICRP (International Commission on Radiological Protection) 2001. *The ICRP Database of Dose Coefficients: Workers and Members of the Public.* ICRP Publication 72. [New York, New York]: Elsevier. TIC: 255638.
Lawrence 2002	Lawrence, A. 2002. "Radiation Risk Estimation from Total Effective Dose Equivalents (TEDEs)." Memorandum from A. Lawrence (DOE) to distribution, August 9, 2002, with attachments. ACC: MOL.20050815.0190.
Luna et al. 1999	Luna, R.E.; Neuhauser, K.S.; and Vigil, M.G. 1999. *Projected Source Terms for Potential Sabotage Events Related to Spent Fuel Shipments.* SAND99-0963. Albuquerque, New Mexico: Sandia National Laboratories. ACC: MOL.19990609.0160.
Luna 2006	Luna, R.E. 2006. "Release Fractions from Multi-Element Spent Fuel Casks Resulting from HEDD Attack." WM'06 Conference, February 26-March 2, 2006, Tucson, Arizona. Tucson, Arizona: WM Symposia, Inc.
NRP 2007	NRP (Nevada Rail Partners) 2007. *Air Quality Emission Factors and Socioeconomic Input Caliente Rail Corridor.* NRP-R-SYSW-EI-0002-02. March 2.
Saricks and Tompkins 1999	Saricks, C.L.; and Tompkins, M.M. 1999. *State-Level Accident Rates of Surface Freight Transportation: A Reexamination.* ANL/ESD/TM-150. Argonne, Illinois: Argonne National Laboratory. TIC: 243751.